A Patchwork Inverse Method in Combination with the Activation Time Gradient to Detect Regions of Slow Conduction in Sinus Rhythm

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Context

- Introduction: Noninvasive electrocardiographic imaging (ECGI) reconstructs epicardial electrical activity from potential measurements on the torso surface.
- Issue
  - ECGI methods are known to produce artificial lines of block in healthy tissue
  - Unclear if ECGI can detect regions of slow conduction in damaged hearts
- Purpose
  - Develop a method to locate the regions of slowed conduction with ECGI
  - Use this method to evaluate the ability of both classic ECGI methods and a new Patchwork Method, to detect these areas

Patchwork Method

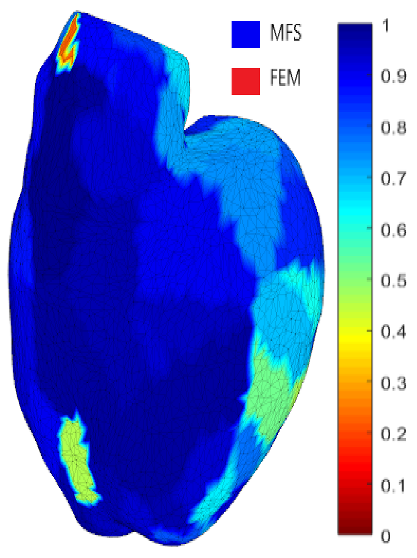
Automatic selection of the optimal solution among several methods (FEM, MFS, BEM) to solve:

$$Au_h = u_T,$$

A: the transfer matrix, u_h: unknown cardiac sources and u_T the torso measurements.
Algorithm:

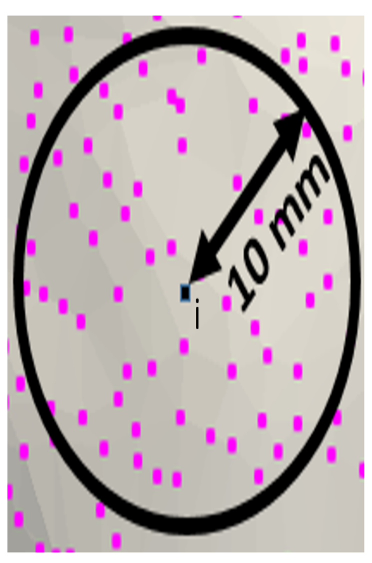
- For each time step n:
  - Compute the approximate solutions $u^n_{h,F}$ and $u^n_{h,M}$ with the FEM and the MFS,
  - Use these solutions to compute the forward solution and the associated residuals $R_B(u^n_{h,F})$ and $R_B(u^n_{h,M})$ on the torso surface using the BEM formulation,
  - For each epicardial point, select the method whose residual is the smallest on the nearest torso point
  - Define $\alpha^n = 0$ if the MFS has the smallest residual, and 1 otherwise,
- For each time step n, compute the new approximate solution as:

$$u^n_h = \alpha^n u^n_{h,F} + (1 - \alpha^n) u^n_{h,M}.$$



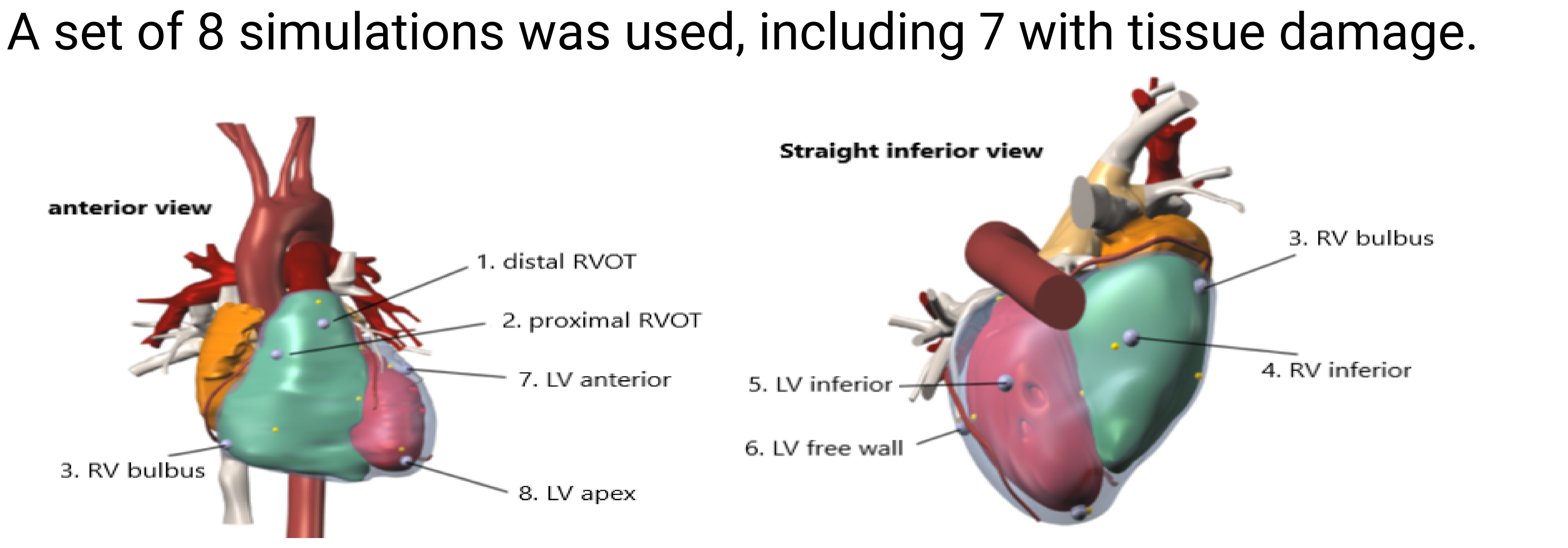
Activation Time Gradient

- An activation time gradient was used to locate regions of tissue damage, with large gradient values corresponding to slow conduction zones
- Compute the absolute difference in activation time between the current node i and the nearest neighboring nodes.
- Five different methods were evaluated to define a single gradient value: maximum, minimum, mean, nearest neighbor and random.



Data

A set of 8 simulations was used, including 7 with tissue damage.



Results

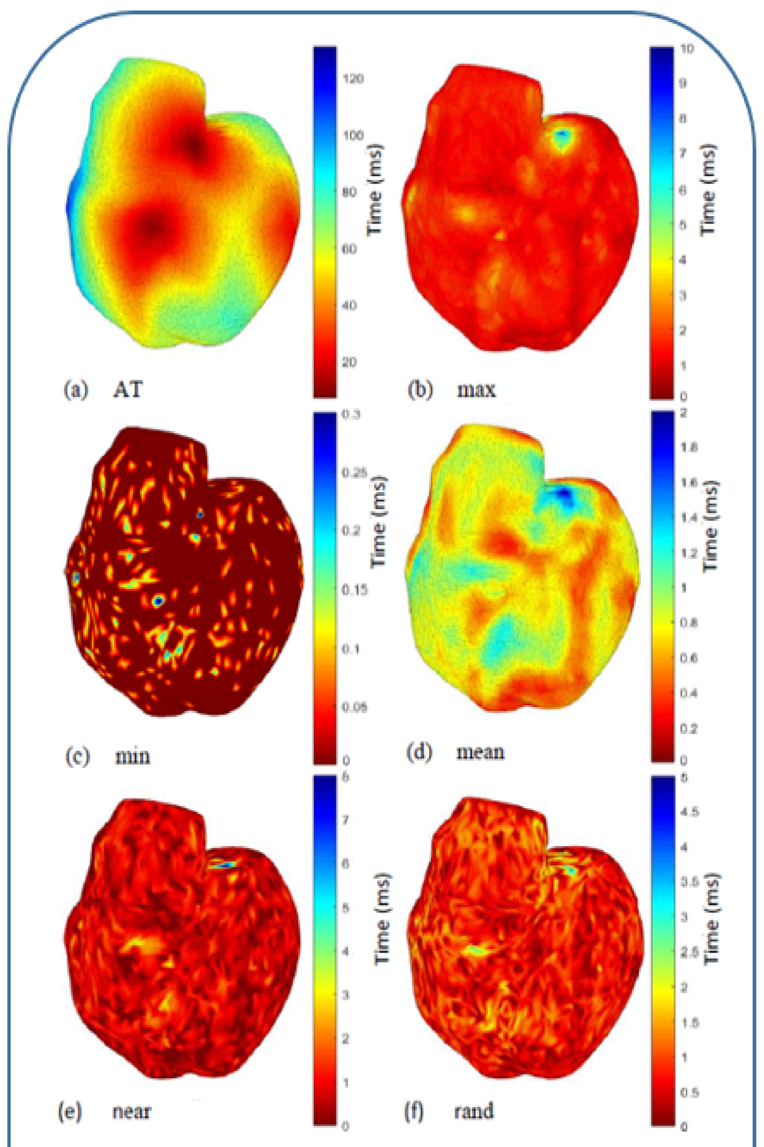


Figure1: Recorded activation time (a) and gradient maps (b--f) calculated with different methods in a case with no tissue damage

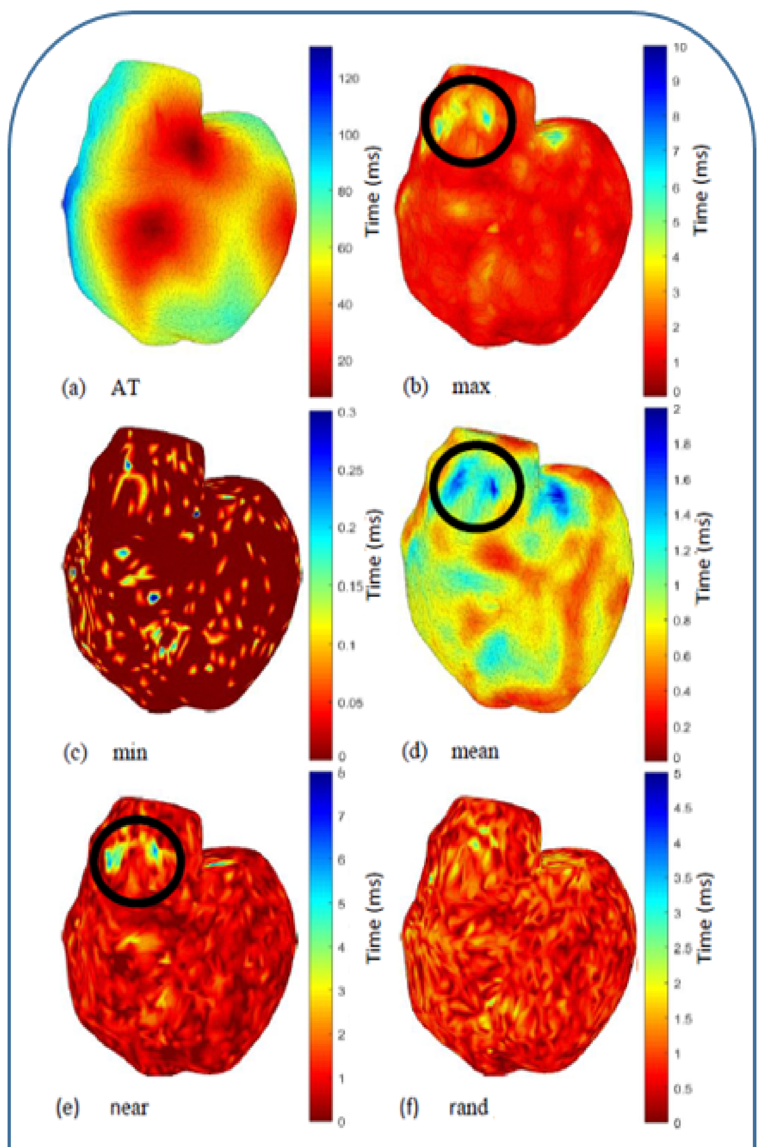


Figure2: Recorded activation time and gradient maps calculated with different methods in one case with a damaged zone indicated bv a black circle

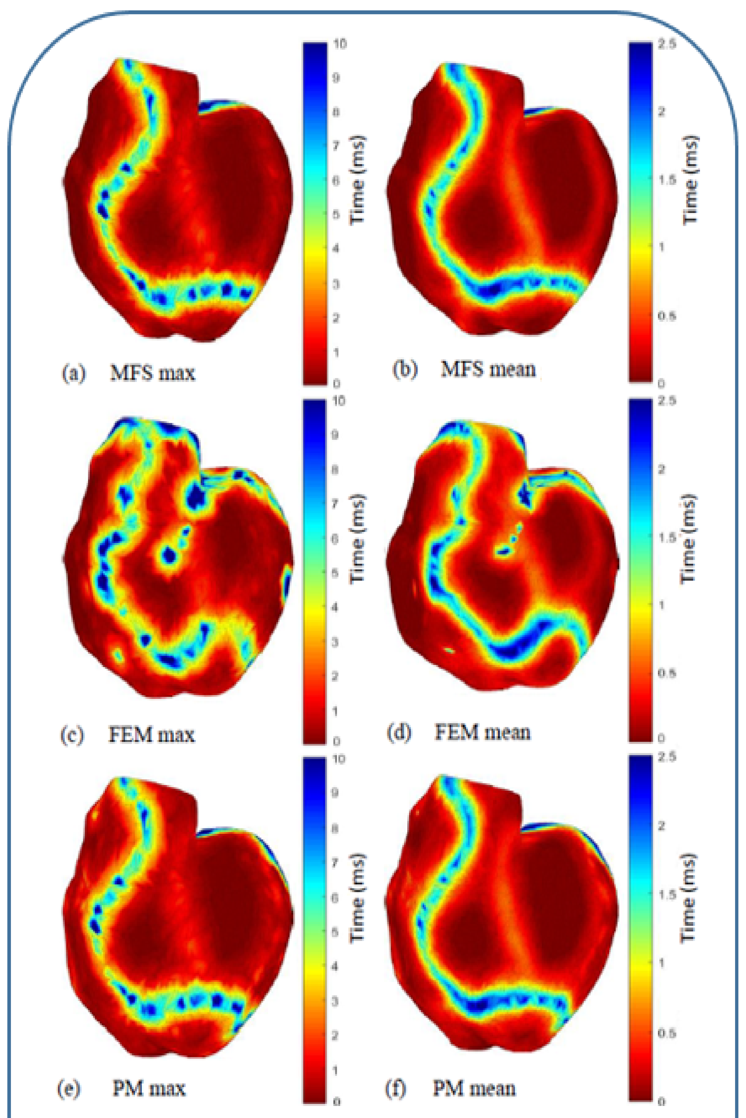


Figure 3: Reconstructed (MFS, FEM and PM) gradient maps calculated with the max and mean methods in the case of no tissue damage

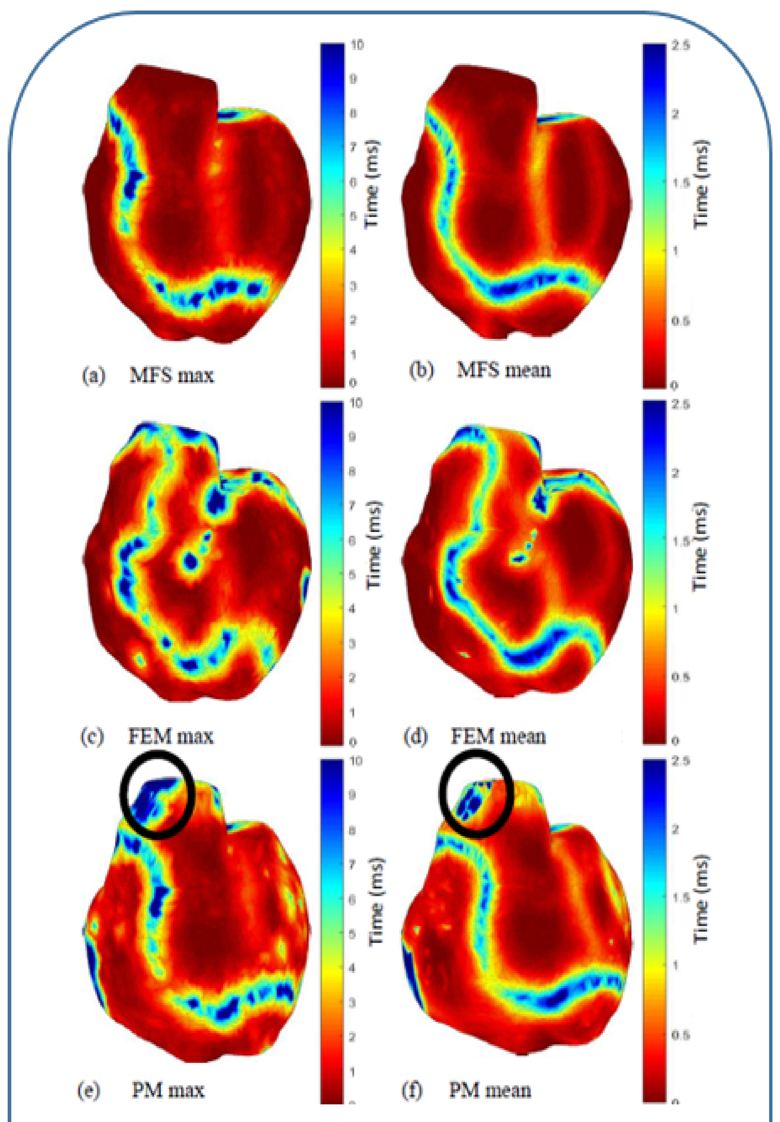


Figure 4: Reconstructed (MFS, FEM and PM) gradient maps calculated with the max and mean methods in a case of tissue damage in the zone indicated by the black circles zone indicated by a black circle

Conclusion

- PM method succeeded in locating 5 of the 6 slow conduction zones recorded,
- MFS and FEM reconstructions did not locate any damaged zones.
- PM overcomes some of the restrictions of current numerical methods, demonstrating its abilities in detecting slowed conduction zones.

References

[1] Bear L., Bouhamama O. et al. Advantages and pitfalls of noninvasive electrocardiographic imaging. Journal of Electrocardiology, 57:15–20, 2019

[2] Bouhamama O., Bear L. and Weynans L., A patchwork method to improve the performance of the current ECGI methods for sinus rythm. In preparation.

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